Water resources and water pollution

Data

- 1/3 of world's people affected by water scarcity. Covers 71% of earth's surface.
- 2.5% percent freshwater and 97.5 % saltwater.
- Most freshwater in glaciers or deep underground.
- 80% of freshwater is icecaps and glaciers; 20% groundwater; 1% surface water
- Surface water is in rivers 1%; organisms 1%; water vapor 8%; soil moisture 38% and lakes 52%
- Only .01% of freshwater is easily accessible by humans
- Agriculture is the single largest user of water in the world. Most of that water is used for irrigating crops.
- Globally 70% agriculture, 20% industrial and municipal uses 10%. But differs widely between countries
- U.S. 46% industry, 41% agriculture, 13% domestic (mostly showers etc.)
- India is 87% agriculture
- Lithuania is 78% domestic
- S. Canada and U.S. have lost well over half their wetlands since European colonization.
- Most abundant water per capita in Iceland, Papua New Guinea, Gabon and Guyana. Middle Eastern and North African countries has the least per person.

Why important?

- Living organisms are mostly comprised of water.
- agent of erosion it changes the morphology of the land;
- acts as a buffer against extreme climate changes when present as a large body of water, and
- flushes away and dilute pollutants in the environment.

Why amazing

- Liquid at room temperature and over a relatively wide temperature range (0 -100°C). This range encompasses the annual mean temperature of most biological environments.
- Requires a large amount of energy is required to raise the temperature of water (i.e., it has a high **specific heat or heat capacity**).
    - Large bodies of water act as buffers against extreme fluctuations in the climate,
    - Makes as an excellent industrial coolant, and
    - Helps protect living organisms against sudden temperature changes in the environment
- Has a very high heat of vaporization.
    - Evaporation helps distribute heat globally; it provides an organism with the means to dissipate unwanted heat.
- Is a good solvent and provides a good medium for chemical reactions, including those that are biologically important.
- Carries nutrients to an organism's cells and flushes away waste products, and it allows the flow of ions necessary for muscle and nerve functions in animals.
- Liquid water has a very high **surface tension**. This, along with its ability to adhere to surfaces, enables the upward transport of water in plants and soil by capillary action.
- Solid water (ice) has a lower density than liquid water at the surface of the earth. If ice were denser than liquid water, it would sink rather than float, and bodies of water in cold climates would eventually freeze solid, killing the organisms living in them.

Water applications:

- Important for all types of industries (i.e., manufacturing, transportation and mining). Often used as an inexpensive solvent and coolant.
- Many manufactured liquid products have water as their main ingredient.

- Chemical solutions used in industrial and mining processes usually have an aqueous base
- Manufacturing equipment is cooled by water and cleaned with water.
- Water is even used as a means of transporting goods from one place to another in manufacturing.
- Nuclear power plants use water to moderate and cool the reactor core as well as to generate electricity. Industry would literally come to a standstill without water.

Freshwater definitions

Surface water-Water collecting on the ground, stream, river, lake, wetland, or ocean

Ground water- Precipitation that infiltrates the ground and becomes trapped in cracks and pores of the soil and rock

Runoff - Does not infiltrate- flows into rivers and streams

Floodplain-areas nearest a river's course that are flooded periodically (deposition of silt make floodplains incredibly fertile as are riparian habitats!)

Watershed-area of land drained by a river and all it tributaries

Water table-top of the accumulation if groundwater is stopped by an impermeable barrier of rock and porous region becomes saturated.

Riparian-riverside

Wetlands-combine elements of fresh water and dry land and are very rich and productive (freshwater marshes, swamps, bogs

Wetland services-slow runoff, reduce flooding, recharge aquifers, filter pollutants

Limnetic zone-open sunlit water, where photosynthesis takes place. Most animal life here.

Profundal zone-sunlight does not reach here. No plant life, less oxygen.

Oligotrophic-lakes and ponds-low nutrient high oxygen

Eutrophic-High nutrient, low oxygen

Benthic zone-bottom of the water body, muddy, rich in detritus and nutrients, low in O_2

Aquifer-Porous layers of sand and rock through which groundwater flows. World's largest aquifer is the **Ogallala Aquifer**, which underlies the Great Plains of the U.S.

Consumptive use-remove water from a source and not return it.

Nonconsumptive use-does not remove, only temporarily removes water from an aquifer or surface water body (hydroelectric power)

Inland Seas. Huge lakes such as Great Lakes (fish found there are lake sturgeon, lake whitefish, northern pike, bass, perch)

- Lake Baikal in Asia is the world's deepest lake
- Caspian Seas is the world's largest freshwater body at 142,000 mi^2

Irrigation is the process of transporting water from one area to another for the purpose of growing crops. We irrigate to increase yields and farm marginal land

Types of irrigation

Worldwide only 45% of water used for irrigation is taken up by crops.

Flood irrigation -flooding of a crop area located on generally flat land. This gravity flow method of water is relatively easy to implement, especially if the natural flooding of river plains is utilized, and therefore is cost-effective. However, much of the water used in flood irrigation is lost, either by evaporation or by percolation into soil adjacent to the intended area of irrigation. Farmland must be flat for flood irrigation so only practical in certain areas (e.g. river flood plains and bottomlands). In addition, because land is completely flooded, salts from the irrigation water can buildup in the soil, eventually rendering it infertile.

Furrow irrigation also involves gravity flow of water on relatively flat land. However, in this form of irrigation, the water flow is confined to furrows or ditches between rows of crops. This allows better control of the water and, therefore, less water is needed and less is wasted. Because water can be delivered to the furrows from pipes, the land does not need to be completely flat. However, furrow irrigation involves higher operating costs than flood irrigation due to the

increased labor and equipment required. It, too, involves large evaporative loss. Flood and furrow irrigation (both very inefficient in terms of saving water resources) account for 90% of irrigation in the world. Over irrigation leads to water logging and salinization.

Drip irrigation involves delivering small amounts of water directly to individual plants. Water is released through perforated tubing mounted above or below ground near the roots of individual plants. This method was originally developed in Israel for use in arid regions having limited water available for irrigation. It is highly efficient, with little waste of water. Some disadvantages of drip irrigation are the high costs of installation and maintenance of the system. Therefore, it is only practical for use on high-value cash crops.

Center-pivot sprinkler systems deliver water to crops from sprinklers mounted on a long boom, which rotates about a center pivot. Water is pumped to the pivot from a nearby irrigation well. This system has the advantage that it is very mobile and can be moved from one field to another as needed. It can also be used on uneven cropland, as the moving boom can follow the contours of the land. Center-pivot systems are widely used in the western plains and southwest regions of the United States. With proper management, properly designed systems can be almost as efficient as drip irrigation systems. Center-pivot systems have high initial costs and require a nearby irrigation well capable of providing a sufficiently high flow. Constant irrigation with well water can also lead to salinization of the soil.

Where do we get our clean water?

In the U.S. water is wasted in industrial and domestic use mainly due to the generally low cost of water. Providing sufficient quantities of clean water in large population areas is becoming a growing problem. Where do we get the water?

Control of water resource

Constructing dams across flowing rivers or streams and impounding the water in reservoirs is a popular way to control water resources.

Advantages, dams:

- allow long-term water storage for agricultural, industrial and domestic use;
- provide new recreational opportunities
- provide new riparian habitat where reservoir is built
- Provide hydroelectric power production and
- Provide downstream flood control.

Disadvantages dams

- disrupt ecosystems, both those where the reservoir is built and downstream
- costly to build
- displace human populations
- destroy good farmland,
- eventually they fill with silt.

Dams

66% of the worlds' largest 227 rivers (77% in N. America and Europe) have been strongly or moderately affected by dams, canals and diversions. Some dams in the U.S. (roughly 500) have been removed as they need repairs or have outlived their usefulness.

Edward's Dam on Maine's Kennebec River one of the first to go. Salmon, Sturgeon, Shad herring alewife and bass almost immediately ventured upstream.

Dikes and levees (long raised mounds of earth) built along the banks of rivers to hold rising water in main channels and prevent flooding.

World's largest dam project is the **Three Gorge Dam on China's Yangtze River** completed in 2004. Cost $25 billion and flooded 22 cities and had to **relocate 1.13 million people**. Also submerged 10,00 year old archaeological site, farmlands and wildlife habitat. Because the sediment is no longer going downstream, the tidal marshes at the Yangtze's mouth are eroding away, leaving he city of Shanghai with a degraded coastal environment.

Colorado River begins in the high peaks of the Rocky Mountains go through the Grand Canyon and empties into the Gulf of CA. Two behemoths of the river are the Hoover Dam and Glen Canyon Dam.

- Since 1922, 7 states along the Colorado have divided the river's water among themselves. Each took according to the needs.
- CA exceeded it allotted portion as the other states didn't need all 'their' water. But that has changed. There is less water and a growing population along the river. To add to that:
    - Scientific data show that megadroughts were common in the past.
    - Climate modelers predict global climate change will bring more drought.
- In Spring 2007, the states allowed upper-basis states to withhold more water than needed so lower basin states had to develop supplies elsewhere.
- Nevada needs a lot more water due to the growth and they want to pump it out of rural areas of eastern Nevada. So far the state engineer has not approved this plan as it threaten the area's ecology.
- If Las Vegas can't get another source, they may back out of the Compact leaving CA in the lurch!
- This was not only a federal issue. Only a limited volume of water reached the Mexican border and this was saline and unusable. The Mexican government complained that their country was being denied use of water that was partly theirs, and as a result a desalinization plant was built to provide a flow of usable water.

Who owns the water?

- Water rights are usually established by law. In the eastern United States, the "**Doctrine of Riparian Rights**" is the basis of rights of use. Anyone whose land is next to a flowing stream can use the water as long as some is left for people downstream. Things are handled differently in the western United States, which uses a "first-come, first-served" approach known as the "**Principle of Prior Appropriation**" is used. By using water from a stream, the original user establishes a legal right for the ongoing use of the water volume originally taken. Unfortunately, when there is insufficient water in a stream, downstream users suffer.

Common law generally gives property owners rights to the groundwater below their land. However, a problem can arise in a situation where several property owners tap into the same groundwater source. The Ogallala Aquifer, which stretches from Wyoming to Texas, is used extensively by farmers for irrigation. However, this use is leading to groundwater depletion, as the aquifer has a very slow recharge rate. In such cases as this, a general plan of water use is needed to conserve water resources for future use.

Klamath County Oregon farmers disobeyed a federal order to divert irrigation waters downstream to save 2 endangered species of fish.

Unsustainable use of groundwater.

Most evident surface water depletion is the Aral Sea. Once the fourth-largest lake on earth (larger than Lake Huron.) Lost 4/5ths of volume in 45 years. On the border of Uzbekistan and Kazakhstan. Cotton farming needed large amount of water. 60,000 fishing jobs gone, wind blow pesticide laden dust from the dry lake bed. North part of Aral Sea being restored.

- 1/3 of world and 99% of U.S. rural population relies on groundwater.
- If depleted, water table drop
- Groundwater becomes more difficult and expensive to extract (Mexico, India, China and other Asian and Middle Eastern nations water tables are falling 2-10 ft. per year.
- If over pumped in coastal areas, salt water can intrude into aquifers, making water undrinkable. Happened in Middle East, Florida, Turkey and Bangkok.
- The land above the aquifer becomes weak and can't support the strata, the land may sink. Cities like Venice, Bangkok, Beijing and Mexico city are sinking
- Sinkholes form when land subsides suddenly.
- Wetlands may dry up. Example the Azraq Oasis in Jordan completely dried up.

Climate change relation to water shortage

- Alter precipitation patterns
- Melt glaciers causing early-season runoff
- Intensify droughts and flooding
- Colorado River basis is already experience drought for the last decade.
- Climate models predict a drier future for the American Southwest

Solutions to depletion of water

1) Get it somewhere else. For example, LA used to get water from Owens Valley and Mono Lake. It desertified the environments of these areas.
2) Desalination-remove salt from seawater or other water of marginal quality through distillation or reverse osmosis
    a. Most desalinization in Middle East.
    b. World's largest reverse osmosis plant in Yuma, Arizona along the Colorado River.
3) Reduce agricultural demand by lining irrigation canals, leveling fields to minimize runoff and adopting efficient irrigation methods
4) Choose crops to match the land and climate
5) Eliminate water subsidies for farmers
6) Xeriscape homes and businesses
7) Eat less meat
8) Install low-flow faucet, showerheads, washing machines and toilets
9) Water plants at night
10) Recycle municipal wastewater

Due to conservation U.S. decreased water consumption by 10% from 1980-1995 even in the face of increasing population.

Water pollution

Non-point sources (farms, city streets and neighborhood
Point sources (factory or sewer pipe)

U.S. Clean Water act targeted industrial discharge, so non-point source is the bigger problem today. Application of fertilizers and pesticides, applying salt to road in winter, changing automobile oil.

The eight classes of water pollutants are:

infectious agents, bacteria, viruses, and parasitic worms enter water from human and animal waste, and cause diseases such as typhoid fever, cholera, hepatitis, amoebic dysentery, and schistosomiasis, a condition marked by blood loss and tissue damage and giardia. Biological pollution by pathogens cause more human health problems than any other type of water pollution.

o**xygen-depleting wastes**, include animal manure in feedlot and farm runoff, plant debris, industrial discharge, and urban sewage. They are consumed by aerobic bacteria. Excessive growth of these organisms can deplete water of dissolved oxygen which leads to eutrophication and the eventual death of oxygen-consuming aquatic life.

inorganic chemicals, include mineral acids, toxic metals such as lead, cadmium, mercury, and hexavalent chromium, and mineral salts. They are found in industrial discharge, chemicals in household wastewater, and seepage from municipal dumps and landfills. The presence of inorganic chemical pollutants in water can render it undrinkable, as well as cause cancer and birth defects. In addition, sufficient concentrations of these chemicals in water can kill fish and other aquatic life, cause lower crop yields due to plant damage, and corrode metals.

organic chemicals, encompass a wide variety of compounds including oil, gasoline, pesticides, and organic solvents. They all degrade the quality of the water into which they are discharged. Sources of these pollutants include industrial discharge and runoff from farms and urban areas. Sometimes these chemicals enter aquatic ecosystems directly when sprayed on lakes and ponds (e.g. for mosquito control). These types of chemicals can cause cancer, damage the central nervous system and cause birth defects in humans.

plant nutrient pollutants, found mainly in urban sewage, runoff from farms and gardens, and household wastewater. These chemicals include nitrates (NO_3^-), phosphates (PO_4^{3-}) and ammonium (NH_4^+) salts commonly found in fertilizers and detergents. Too much plant nutrients in the water can cause excessive algae growth in lakes or ponds. This, in turn, results in the production of large amounts of oxygen-depleting wastes. The subsequent loss of dissolved oxygen causes eutrophication of the lakes or ponds.

sediments, Erosion of soils is the main process contributing **sediments**, or **silts**, to water bodies. Sediments can cloud the water of streams and rivers, reducing the amount of available sunlight to aquatic plants. The concurrent reduction in photosynthesis can disrupt the local ecosystem. Soil from croplands deposited in lakes and streams can carry pesticides, bacteria, and other substances that are harmful to aquatic life. Sediments can also fill up or clog lakes, reservoirs, and waterways limiting human use and disrupting habitats.

radioactive materials and such as iodine-131 and strontium-90 are found in nuclear power plant effluents and fallout from atmospheric nuclear testing. They can be introduced into the food chain through plants and become incorporated in body tissues of humans and animals. Their ionizing radiation can produce cancers, especially in the thyroid and bone where they tend to concentrate.

Thermal pollution. A power generating plant commonly discharges water used for cooling into a nearby river, lake, or ocean. Because the discharged water can be significantly warmer than the ambient environment, it represents a source of **thermal pollution.** Industrial discharges are also sources of thermal pollution. The increased temperature of the water may locally deplete dissolved oxygen and exceed the range of tolerance of some aquatic species, thus disrupting the local ecosystem.

Treating water waste

Processing water in treatment plants can reduce the amounts of infectious agents, oxygen-depleting wastes, inorganic chemicals, organic chemicals and plant nutrients.

Bans and restrictions on the use of certain chemicals, such as those on DDT and hexavalent chromium compounds, are also very helpful in reducing the amounts of these chemicals in the environment. By limiting exposure to these harmful substances, their negative effects on humans and local ecosystems can be greatly reduced.

Indicators of water quality

1) Fecal coliform bacteria
2) Algae and aquatic invertebrates
3) Nutrient concentrations (nitrogen, phosphorus)
4) Taste and odor
5) Hardness
6) Dissolved oxygen
7) Turbidity
8) PH
9) Temperature

Waste water treatment

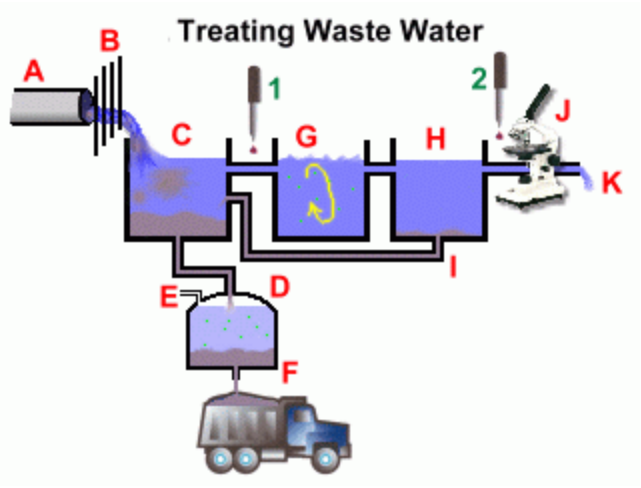
Primary treatment –removes 60% of suspended solids

Secondary treatment-water stirred and aerated so aerobic bacteria degrade organic pollutants (now 90% of suspended solids removed)

Treat water with chlorine and sometime UV light to kill bactiera

Then often goes to rivers or oceans (may be ‘reclaimed and used for lawns and golf courses or industry.)

Sludge (solids) is sent to digesting vats. The result of biosolids is then dried and either put in landfill, incinerated or used as fertilizer on cropland. Methane rich gas is sometimes burned to generate electricity. Natural wetlands can help purify water and restore habitat for wildlife.



Waste water enters the treatment area from town sewers (**A**). It is screened (**B**) to remove large objects.
The liquid is stored in a settling tank (**C**) where solids suspended in the water can settle to the bottom. This sludge is collected, and bacteria are added (**D**), which consume organic waste. Gases produced by this process are collected (**E**) and sold as fuel; the remaining sludge is dried and buried, burned, or sold as fertilizer (**F**).

Meanwhile the water has chemicals added to remove phosphates (**1**) and is then moved to aeration tanks (**G**), where oxygen is added, and bacteria consume any organic materials. A final settling tank (**H**) allows remaining solids to be collected (**I**).

The water has chlorine added (**2**) to kill any remaining bacteria, and the water is tested (**J**) before being returned to the lake or river (**K**).

Treating Drinking Water

Water used by a town or city is drawn from a lake or river or reservoir, but needs to be treated first to make sure it is safe to drink. The intake pipe extends far out into the lake or river, where it draws in a supply of water which is sent to a treatment plant.

Chlorine is added (**1**) to kill microorganisms. Alum and lime may also be added (**2**). Alum causes suspended particles to clump together, making them easier to remove. Lime changes the pH level, if required. The water is stirred in a large tank (**3**) to make the suspended solids clump together; they are then allowed to collect on the bottom of a settling tank (**4**). Next the water is passed through a series of filters (**5**), which may include sand, carbon, gravel and rocks. Sand helps remove any remaining solids, algae and silt. Carbon removes taste and odor-producing chemicals from the water by adsorption. Chlorine is added (**6**) to again kill algae and micro-organisms, and the water is sent to a storage tank (**7**) for distribution to homes.